



Intelligent Collaboration & Visualization

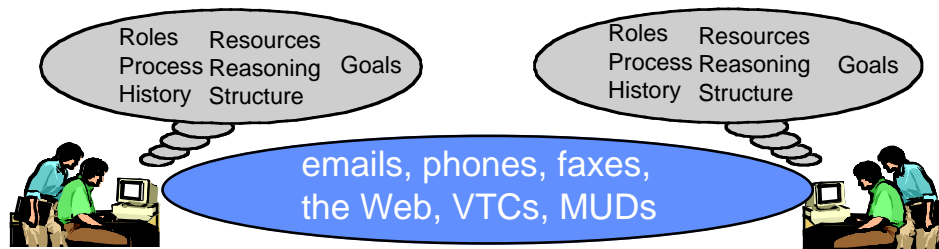
Kevin Mills

Many DARPA programs invest in advanced technology for human-computer interaction; however, few programs consider harnessing that technology for teams of people supported by computer interactions across distributed systems. In the commercial sector, recent progress addresses computer support for collaborating groups of people, where groups are homogeneous actors all working together equally for a common objective. Also in the commercial world, current products orchestrate work flow among organizations; such work flow products tend to codify rigid organizational processes. In addition, commercial products for collaboration via video and audio streams require substantial homogeneity in the bandwidths, display systems, and computers involved in multimedia conferences. Little commercial support exists for collaboration among groups on the move. Current and future military systems will require scaleable, interoperable middleware and tools enabling problem solvers to collaborate on the move across time and space. The current commercial directions for collaboration technology will not lead to collaborative software and systems that will meet these critical military needs. The Intelligent Collaboration & Visualization (IC&V) Program will develop technology that will enable commercial suppliers to meet the collaboration requirements of future military systems. Two thrusts will be pursued:

- **Address Priority Military Needs In Collaboration Technology**
The IC&V program will enable collaboration across variable bandwidths and computing and display environments among mobile collaborators with time-critical needs, will reduce the time needed to construct collaborative applications, and will enable collaborations to be configured quickly in response to unforeseen topologies. These are existing military needs not currently recognized as commercial requirements.
- **Advance Basic Collaboration Technology**
The IC&V program will enable collaboration systems to represent a greater portion of the collaboration context, and thus, to provide collaborators with more intelligent assistance (for example, enhancing collaboration among teams of teams, discovery of relevant collaborators and information in real-time in the context of a task, and rapid setting of a collaboration context) than is available from today's collaboration systems, or from any collaboration systems projected to be available from the industry in the next 5 years. The IC&V program will move current DARPA investments in human-computer interaction toward investments in team-computer interaction. Increasingly, the power of the combined computer-network system of systems must accrue to teams and not solely to individuals.



Intelligent Collaboration & Visualization Current State of Collaboration Technology



Current State of the ART...

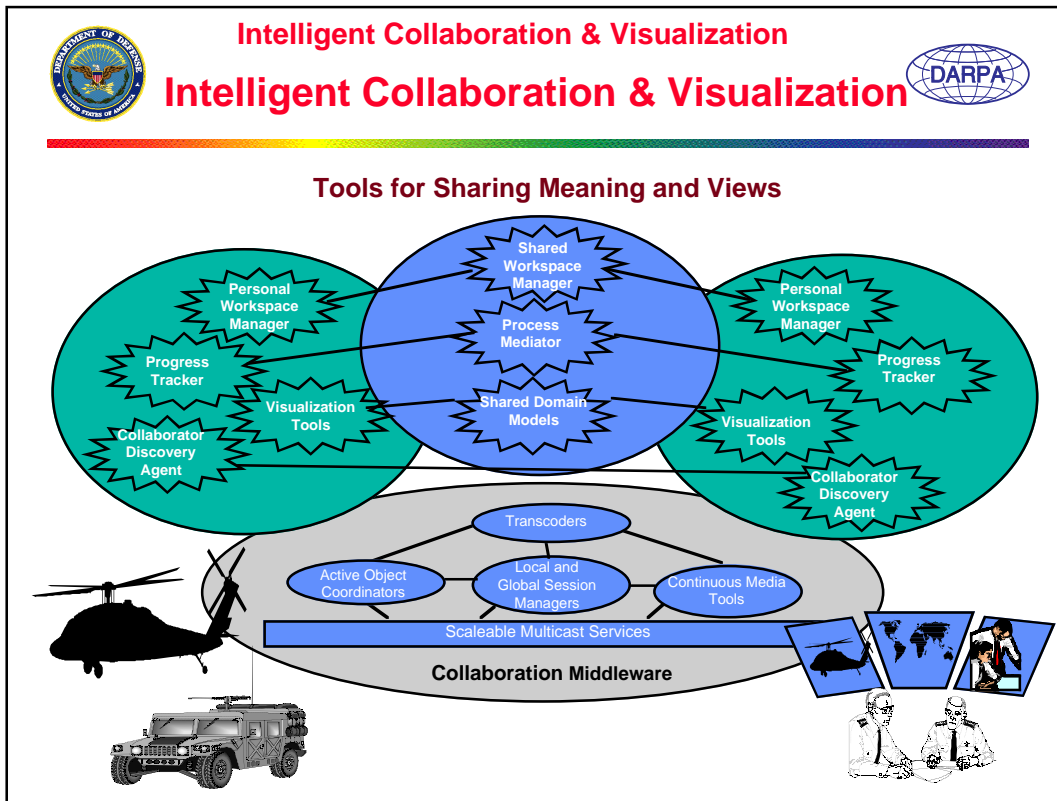
- Videoteleconferencing supporting a few coding standards
- Multicast Backbone and related tools for video, audio, and shared whiteboard with poor synchronization qualities and limited support for interaction
- Multi-User Domains (MUDs) with text-based and 3-D graphical interfaces
- Shared X Applications
- Commercial Groupware and a growing number of Web-based Collaboration Tools
- Special-purpose Shared Applications

Limitations

- Does not scale in several dimensions
- Little interoperability among heterogeneous collaboration systems
- Weak support for asynchronous collaboration
- No support for context-based discovery of relevant collaborators and information
- Rigid (if any) process support
- Collaborators get lost in a morass of irregular data

Support for group and team interaction requires communication (sharing bits), collaboration (sharing information), and coordination (sharing process). Currently, commercial suppliers assume communication among collaborators to be: 1) fairly homogeneous in bandwidths and computing and display technologies; 2) low in mobility; 3) limited in the availability of multicasting; and 4) high in group stability. These assumptions are not appropriate in a military context. Communicating teams in the military use a wide range of bandwidths, from 9.6 Kbps radio links through 20 Mbps broadcast satellite links. In addition, current DARPA investments in mobile information systems and multicasting technology indicate that future military systems will make liberal use of mobility and multicasting technology to support communications among mobile teams. Some team members will be in the field carrying body-mounted computing and communications equipment, some will be in terrestrial and airborne vehicles, some will be a part of rapidly deployable and intermittently mobile headquarters units, and some will be in fixed locations. In addition, teams of teams will need to interact while on the move. Current collaboration technology uses communications channels to convey representations of ideas without significant automated support for shared collaboration context and provides shared same-view bit maps that allow collaborators to add to the bit maps. The general model is to convert semantic information to a bit map, draw other bit maps over the base bit map, and store the resulting bit map as a file. This form of bit-mapped shared whiteboard, while useful, does not incorporate enough semantic representation about the objects being shared.

Summary of Limitations of Current Collaboration Technology: 1) does not scale across bandwidths, computer and display technologies, and changing group compositions; 2) provides limited interoperability among consistency and coordination protocols, dynamic resource allocation schemes, and encoding formats; 3) provides weak support for asynchronous collaborations; 4) provides no support for context-based discovery of relevant collaborators and information; and 5) provides either no support for collaboration processes or provides support that is overly rigid. In addition, collaborators deal with a wide range of irregular information (e.g., faxes, pictures, video and audio clips) that must be related into a collaboration context and become accessible readily when needed. Access to irregular information currently requires users to store the information into a hierarchical file system. Later, to retrieve the required information the user must search the file system exhaustively, without the advantage of the context in which the information was received and stored.



The IC&V program aims to develop **collaboration middleware** addressing the military priorities of heterogeneous bandwidths and computer and display technologies, high mobility, and varying group size. Examples of projected functions within the IC&V middleware include the following:

- Scalable, reliable, multicasting protocols to facilitate high-efficiency, semi-reliable communications among dynamic groups
- Approaches to generate and place transcoders to meet requirements for security, performance and function
- Local session management algorithms to arbitrate access to non-sharable devices, to allocate local resources among modalities based on task focus, and to synchronize timing among related but separate data streams
- Global session management algorithms to allocate resources among session components, such as algorithms for adaptive distributed bandwidth allocation within a session, distributed floor control algorithms, and mechanisms for exercising remote control for a shared conference resource (such as a video camera)
- Protocols for distributing and controlling active objects (e.g., animation).

The IC&V program also aims to develop **tools for sharing meaning and views**, tools that address the need to represent collaboration context and semantics in a form that will permit computers to provide collaborators with intelligent assistance and to enhance the ability of collaborators to view the ideas and concepts involved in collaborative tasks. Examples of projected IC&V tools for sharing meaning and views include the following:

- Tools to aid the discovery of relevant collaborators and information within the context of a task
- Tools to provide interconnected, focused and role-based views from shared domain models; thus, allowing specific team members to see information relevant to their individual roles and expertise, but within the context of a shared situation
- Tools to support tracking of local progress toward a task's solution within the context of global, shared progress among a team, even in the face of intermittent connections between team members
- Tools to manage irregular information (e.g., faxes, audio/video clips, email) related to collaborations, both within personal and shared workspaces, to control sharing of personal information, and to provide indexed, synopsisized conference archives accessible both outside and within a synchronous conference.



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Goals and Objectives



Develop the generation-after-next collaboration middleware and tools that enable military components and joint staff groups to:


- Gather appropriate problem solvers together across time and space for rapid response in time-critical situations
- Bring appropriate information resources together across time and space within the context of a task
- Enhance the effectiveness of collaborating problem solvers

Specific objectives:

- Enable access via diverse portals, from hand-held through room-sized
- Enable interoperability across diverse encoding formats, coordination and consistency protocols, and real-time services
- Scale collaborations to 10 active contributors, 100 questioners, and 1,000 observers
- Reduce by an order of magnitude the time needed to generate collaborative applications
- Enable real-time discovery of relevant collaborators and information within task context
- Reduce by an order of magnitude the time to establish collaborative sessions across heterogeneous environments
- Reduce by an order of magnitude the time to review collaborative sessions
- Improve task-based performance of collaborators by two orders of magnitude


The general goals of the IC&V program address military requirements for problem-solving in response to task assignments that have a time-critical nature, that involve distributed team members or teams of teams, where some teams and/or team members can be mobile. Specific objectives were chosen to provide some concrete definition of scope for the program, as explained below.


- **Diverse access portals** - Military operations call for a wide range of access devices within a collaborating team.
- **Interoperability** - Military operations call for a range of bandwidths among collaborators; thus, encoding methods will evolve toward adaptive, layered encoding strategies that must interoperate with standard commercial encoding strategies optimized for a limited set of bandwidths. In addition, international military operations can require interworking with collaboration solutions from a range sources.
- **Group Size** - Research suggests that groups of more than 20 people do not perform effectively. The IC&V program strategy focuses on automated tools that enhance the effectiveness of small (10 person) teams working actively together, while coordinating with other teams (10 X 10 = 100 questioners), and providing visibility to a larger set of interested parties (1,000 observers).
- **Generation Time** - Not every collaborative application can be devised in advance of a need. In current best case, development of collaborative applications can take 9-12 months; the IC&V target is one month or less.
- **Collaborator Discovery** - Currently, collaborators must be known a priori, but in a military context, as various people work in separate teams on individual problems, opportunities for productive collaboration can arise, yet go unnoticed and therefore not exploited.
- **Session Establishment** - Currently, establishing a synchronous conference can take 4 hours of lead time to manually schedule and configure multi-point conferencing units across administrative domains and service providers. Military requirements for conference establishment are not so predictable as to location and configuration, and yet, when a conference is required, timeliness can be important.
- **Session Review** - Military personnel are often hurried into an ongoing collaboration, yet lose valuable time trying to understand what has transpired within a collaborative situation. Can 10 hours of collaboration be comprehended within 1 hour?
- **Task Performance** - The ultimate purpose for the IC&V program technology is to improve the problem-solving performance of teams assigned to specific tasks. For example, can a 72-hour air campaign-planning application be accomplished within 8 hours, while allowing continued planning and even the redirection of sorties that are in progress?



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An Example of Military Relevance: Joint Forces Air Component Commander (JFACC) Needs



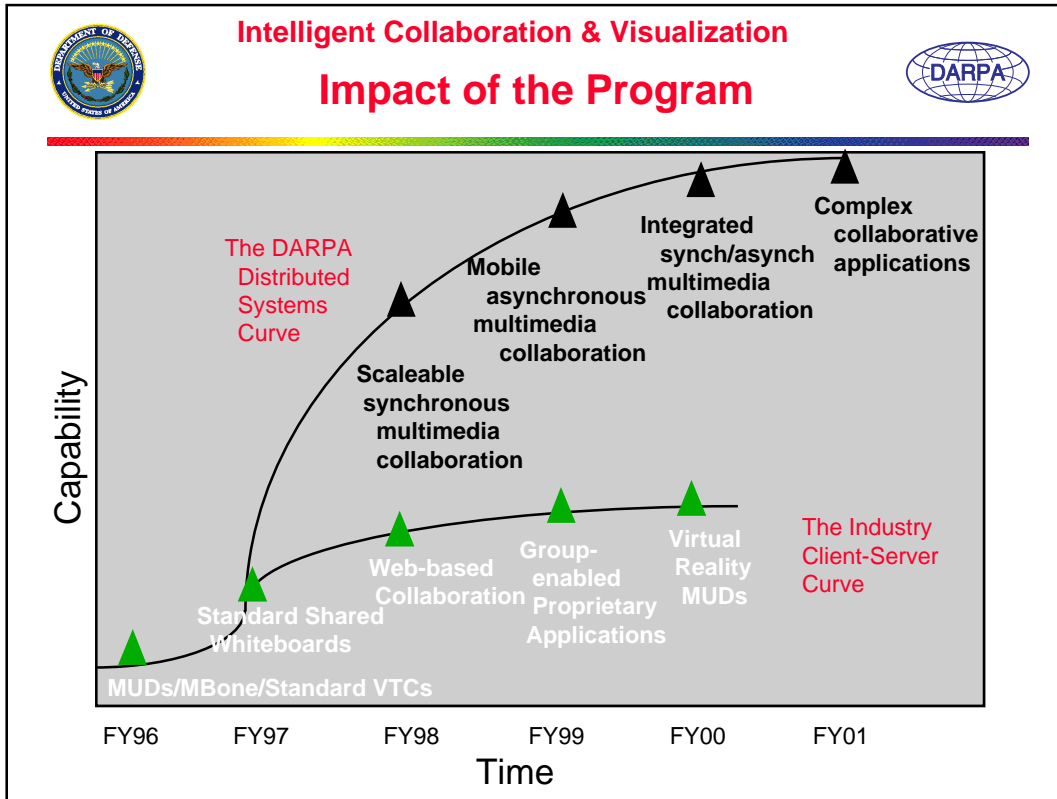


- **Collaboration**
 - among JFACC planners
 - with other JTF planners
 - with inflight missions for redirects
 - with other components outside the theater of operations
- **Shared databases, applications, and visualization tools**
- **Shared access to representation of plan, including objectives, tasks, decision sequence, rationale, and link back to parent objectives**
- **Ad hoc group formation based upon capabilities and security restrictions**

The text on this slide was taken from a briefing of the Joint Forces Air Component Commander (JFACC) program within DARPA ISO. JFACC is only one of many military programs involving collaboration. In fact, more and more DARPA is realizing that most military applications involve teams that must collaborate. While much of the focus of Information Technology research has been on improving the productivity of individuals, the future should find more emphasis on improving the productivity of individuals within the context of teams and on improving the productivity of teams.

Other examples of the Federal Government's need for collaboration technology include the following:

- The National Photographic Interpretation Center (NPIC) has a program that attempts to exploit existing technology for collaboration even across DOD and civilian agencies (such as USGS). This program is identifying needs for advanced collaboration technology.
- The intelligence community at large, as shown within Intelink, has demonstrated needs for collaboration technology.
- The Armed Forces Information Service (AFIS) has expressed collaboration technology needs and has expressed interest in providing a testbed for collaboration technology.
- The Department of Energy (DoE) plans to invest substantially in FY97 in technology to support collaborative science and the sharing of scarce laboratory resources.
- The National Science Foundation (NSF) has a program in coordination theory and collaboration technology and also funds several national collaboratories.



Commercial Systems Today - The commercial market is delivering a range of standard videoteleconferencing (VTC) and desktop conferencing (DTC) products aimed mainly at relatively static configurations and the support of a few bandwidths. In addition, proprietary groupware systems (such as Lotus Notes) exist, along with some Web-based chat and voice applications.

DARPA Systems Today - The Joint Task Force (JTF) program is working toward next-generation systems for military collaboration, based on ITO-funded, MBONE tools and on ISO-developed, special purpose, shared applications built on CORBA. The Computer-Aided Education and Training Initiative (CAETI) is providing some seed work for advanced collaboration technology. The DSO MADE program is developing technology to capture, organize, and describe design information in a design web to facilitate serial collaboration across time.

Expectations without an IC&V program - A number of commercial products will be developed that give shared-user access to applications based on the T.120 standard. We can expect to see an increasing number of Web-based collaboration tools and systems. We can expect office suite vendors to group-enable their proprietary applications. We might expect to see an increasing number of virtual reality Multi-User Domains (MUDs).

Expectations with an IC&V program - DARPA can leverage current and future investments in advanced networking (mobility, multicast, and resource reservation protocols) to: 1) achieve scaleable synchronous multimedia conferencing, with fast setup times, that can adapt to heterogeneous bandwidths and computing and display capabilities; 2) add the ability to support mobility and asynchronous collaboration through archiving and through increasing the power of semantic representations within collaboration systems; 3) integrate the ability to collaborate synchronously and asynchronously; and 4) provide a software platform for constructing complex collaborative applications in a timely fashion as specific application needs are identified.



Intelligent Collaboration & Visualization



Tasks

Task 1: Develop Collaboration Middleware

Develop software, leveraging next-generation networking technology, for collaboration across bandwidths, group size, and computing and display environments to gather appropriate problem solvers together across time and space for rapid response in time-critical situations.

Task 2: Develop Tools for Sharing Meaning

Develop shareable semantic structures, including techniques for automatically capturing, summarizing, and indexing collaborative sessions, to bring appropriate information resources together across time and space within the context of a task.

Task 3: Develop Tools for Sharing Views

Develop visualization software that enhances the effectiveness of collaboration by adapting views based on task, by enabling manipulation among groups, by representing various collaboration spaces, and by supporting multimedia annotations.

Task 4: Prototype and Evaluate Collaborative Applications

Develop, instrument, and evaluate prototype collaborative applications to assess the IC&V technology against the specific program objectives.

The IC&V program is organized as four tasks:

- The first task aims to develop collaboration middleware that can bring collaborators together on the move across time and space, while adapting to variations in bandwidth, group size and configuration, and computing and display environments. The goal is to create a domain model for collaboration middleware, to populate the model as a library of components that can be used to generate collaborative applications, and to demonstrate that applications built on the model and components can scale to the 10 active contributors, 100 questioners, and 1,000 observers identified as IC&V objectives.
- The second task aims to develop shareable semantic structures for describing collaboration objects and the relationship between those objects in a form that can be understood by human collaborators and computer programs. Special emphasis will be placed on: 1) techniques for creating shareable domain models that can support multiple tasks within a domain; 2) methods for capturing, summarizing, and indexing collaborative sessions; 3) tools to help users structure and annotate irregular information associated with collaborations; and 4) semantic structures and algorithms that enable automated assistance in the discovery of relevant collaborators and information.
- The third task seeks to exploit visualization technology to enhance the effectiveness of collaborations. At least four ideas will be investigated. First, can individual views of a situation be adapted based on the roles taken within a collaboration in order to improve the effectiveness of a problem-solving team? Second, can teams share the control of animation in a form that will improve the communication among the team? Third, can novel means of representing collaboration spaces and shared objects improve the effectiveness of collaborations? Fourth, do multimedia annotation techniques enrich the communication among asynchronous collaborators? Other ideas might also be investigated.
- The fourth task has two main foci: 1) develop methods to instrument and evaluate IC&V technology against the goals and objectives of the program; and 2) prototype some representative applications using IC&V technology. This task is meant to engage the user community to assess the emerging technology and to identify opportunities for technology transfer.



Intelligent Collaboration & Visualization Technology Investments



Task 1: Develop Collaboration Middleware

- Scaleable Coordination Architectures and Protocols
- Transcoder Generators
- Composable Collaboration Systems

Task 2: Develop Tools for Sharing Meaning

- Self-describing Objects and Structures
- Context-sensitive Indexing
- Group-evolvable Processes

Task 3: Develop Tools for Sharing Views

- Multicast, Time-correlated, Active Objects
- Interconnected Display Protocols
- Multimedia Annotation Techniques

Task 4: Prototype and Evaluate Collaborative Applications

- Evaluation Metrics and Instrumentation Methods
- Collaborative Applications

This slide simply provides a few examples under each task of areas in which the IC&V program expects to make technology investments. This summary was extracted from the following five slides that list some of the challenges faced by the IC&V program. The next five slides also cite at least one possible approach that might address each challenge.



Intelligent Collaboration & Visualization

Task 1: Develop Collaboration Middleware



Key Challenge	Approach
Scale from small to large groups and to groups of groups	<ul style="list-style-type: none">• Design coordination architectures and protocols to manage local interactions among collaboration tools and to provide global session management, including distributed floor control and global conference bandwidth management• Model session and resource characteristics, object execution/transmission demands, and application requirements; develop rule-based resource placement algorithms• Unite multicast technology with mobile code and distributed object systems
Bridge diverse control protocols and media formats	<ul style="list-style-type: none">• Develop collaboration domain models and protocols to provide generic representations of collaboration functions; develop default implementations of the collaboration functions• Develop transcoder generators to enable translation between generic and local representations of collaboration functions
Compose collaborative applications	<ul style="list-style-type: none">• Apply composite system techniques; specify APIs for the generic collaboration model; develop default implementation of model components

Group Size - The IC&V technology needs to improve the quality of interactions among small (10 person) teams, while at the same time allowing teams of teams (10 X 10) to interact and allowing a larger population to have insight into a collaboration (1000's), perhaps for purposes of information discovery.

Interoperability - The IC&V technology must bridge diverse control and coordination protocols, real-time services, and encoding schemes. This challenge is inherent in the military need to adapt to both anticipated and unanticipated collaborations, involving both differences in resources and differences in protocols and encoding schemes.

Composability - The IC&V technology must enable collaborative applications to be constructed within a month of an identified need. This means that the model and components provided by the program must be as complete as feasible and that the composition technology must be flexible, enabling the substitution of new components for existing components over time.



Intelligent Collaboration & Visualization

Task 2: Develop Tools for Sharing Meaning



Key Challenge

Approach

Discover, describe, and share semantic structure within irregular information associated with collaborations

- Develop tools for incrementally specifying and sharing semantic structures of irregular information that can be interpreted by both humans and machines
- Develop languages for specifying self-describing objects and structures that enable semantic content to be shared among dissimilar systems
- Develop methods, based on statistical methods for concept clustering to map between semantically similar concepts expressed in different terms

Set context for asynchronous collaborators

- Develop methods to create multiple-linked, context-based, multimedia collaboration spaces containing collaboration objects and segments of continuous media streams; develop tools for condensed review of long, collaborative sessions

Digital collaborations typically involve a great deal of digital information that arrives in a variety of forms (e.g., faxes, electronic mail messages, images, video/audio clips) that can have semantic relationships. Often the relevant semantic information resides only in the minds of the collaborators who use rather primitive methods (hierarchical directories) to sort and store the information for later use. A key challenge for the IC&V program is to provide assistance to help users discover, describe and share semantic structure in a form that can allow a user to recall relevant information based on the context in which it was used and on other situations in which the information might apply.

Today, most synchronous collaborations occur in a form that is lost to those not present during the discussions. A key challenge for the IC&V program is to capture the essential information from synchronous collaborations in a form that will enable asynchronous collaborators to quickly determine the state of a collaboration that occurred without their involvement.



Intelligent Collaboration & Visualization Task 2: Develop Tools for Sharing Meaning



Key Challenge

Discover relevant collaborators and Information in real-time within the context of a task

Provide adequate yet not overly constrained support for collaboration process

Approach

- Develop tools for context- and task-based similarity and difference analysis based on machine-annotated semantic links and graph matching algorithms coupled with GOMS (Goal, Operations, Methods, and Selection rules) models
- Develop techniques that enable collaborating groups to specify and evolve process rules
- Apply machine-learning techniques to identify effective matches between process rules and collaboration structures and objectives
- Migrate successful process rule sets and related context knowledge into the collaboration component software

Today, collaborators must typically know what information is required to support a collaboration and must know the identity of collaborators prior to a collaborative session. Primitive mechanisms exist to enable a user to conduct out-of-band searches for relevant information and people. Improvements in the timeliness and automation of the search process would create benefits for users. A key challenge for the IC&V program is to enable relevant collaborators and information to be discovered in real-time within the context of a task.

The most successful collaboration systems today seem to provide little or no support for controlling the collaboration process. Such systems, for example videoconferencing and electronic mail, enable collaborating users to exercise process conventions outside the system and without the aid of the system. The key to the success of such systems is flexibility. Current systems that provide mechanisms for strict process control through workflow specifications seem to be less successful. Perhaps the cost of describing a process is too high. Or perhaps the nature of collaboration requires the flexibility to adapt process to the desires of the collaborators. A key challenge for the IC&V program is to provide adequate, yet not overly constrained, support for collaboration process, perhaps by developing technology that will allow collaborating teams to define, evaluate, and evolve suitable processes as the nature of the collaboration changes and as the size of a team varies.



Intelligent Collaboration & Visualization

Task 3: Develop Tools for Sharing Views



Key Challenge	Approach
Match visualization and interaction techniques to needs of humans and tasks	<ul style="list-style-type: none">• Study the relationship between human task performance and visualization/ interaction techniques; develop software libraries for real-time control and viewing of dynamic information systems; develop software libraries for dynamic rendering of information based upon context and display capabilities• Develop techniques for multimedia annotation of visualizations
Share and coordinate complex, interactive visualizations among collaborating groups	<ul style="list-style-type: none">• Develop models and protocols for sharing 3-D immersive visualizations among collaborators; develop software libraries, including APIs, to implement the models and protocols• Develop protocols for shared, interactive control of 3-D immersive visualizations• Develop protocols for shared, interactive control of role-based, interrelated visualizations• Apply multicasting and time-correlation techniques to develop interactive control methods for replicated, active objects

Today, visualization software provides a programmer's choice of appropriate methods to view specific information. More advanced approaches might enable visualization software to adapt a user's view based on a combination of the capabilities of display hardware, the needs of a specific user, and the requirements for a specific task. A key challenge for the IC&V program is to develop methods to match visualization and interaction techniques to combinations of specific display hardware, humans, and tasks.

Today, most advanced visualization research focuses on improving the ability of single users to assimilate complex information spaces. While this research direction remains important, visualization techniques must increasingly focus on multi-user collaborations. The current state-of-the-art, where groups of collaborators share a single view of a given situation, remains much too limited to support effective cooperation among teams of users, each having a specific role and expertise. A key challenge for the IC&V program is to develop methods to share and coordinate complex, interactive visualizations among collaborating teams.



Intelligent Collaboration & Visualization Task 4: Prototype and Evaluate Collaborative Applications



Key Challenge

Approach

Assess the technical approach

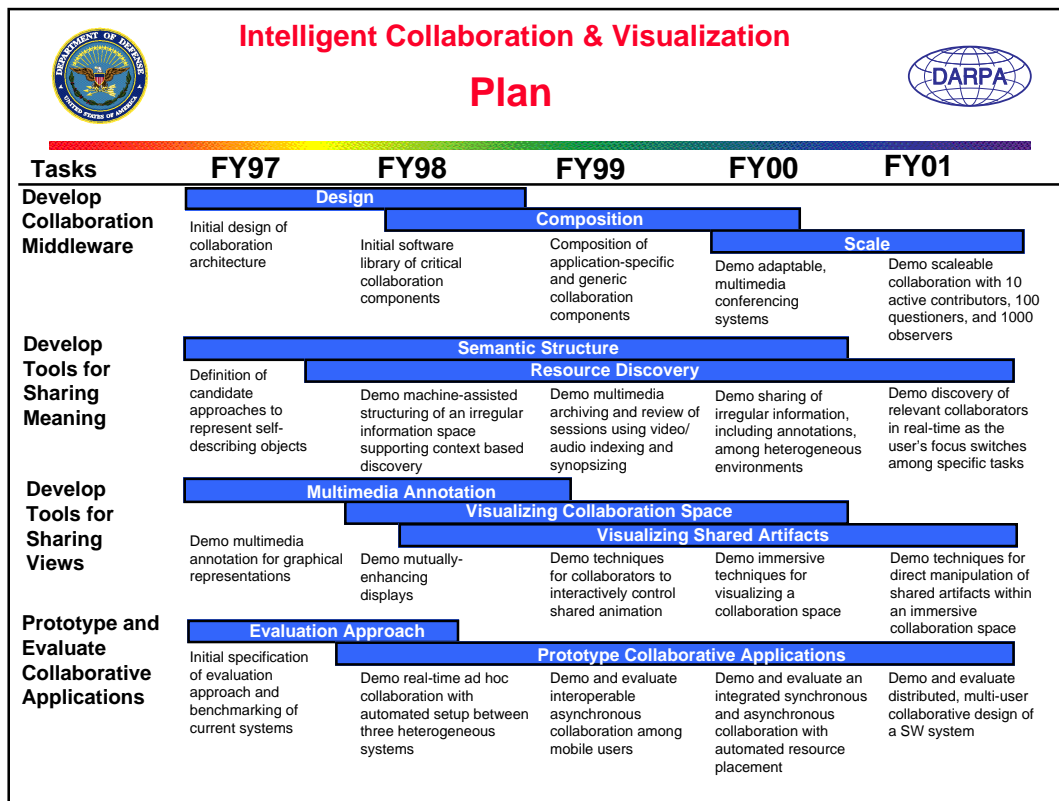
- Develop evaluation metrics for task performance, for scalability, for interoperability, and for composability
- Develop techniques to instrument collaboration systems
- Identify, develop, instrument, and evaluate collaborative systems, with military relevance, that are built using technology from the program

Maximize commercial acceptance of the collaboration architecture

- Develop an open and extensible architecture that permits incorporation of additional application components, both sharing-aware and sharing unaware

Relatively little literature exists to guide the evaluation of information technology applied to problem-solving teams. For this reason, a key challenge for the IC&V program is to develop metrics, instrumentation techniques, and evaluation approaches to assess the effectiveness of the technology developed in the program.

To provide maximum leverage for the DOD, technology developed within the IC&V program must be incorporated within commercial collaboration products; thus, a key challenge for the IC&V program will be to maximize the commercial acceptance of the collaboration architecture produced within the program.



This chart depicts each of the four tasks within the IC&V program across 5 years, with a key milestone listed each year for each task. After the first year, the general plan calls for a demonstration of at least one new capability related to each task in every year. The plan also divides each task into two or three major themes that relate to the objectives being pursued in the task and to the milestones being completed. The plan is intended to guide the direction of the research and to provide help in assessing the progress made within the program.